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PULSED EXCIMER LASER PROCESSING

ARCO SOLAR, INC.

David Wong

Goal

TO DEMONSTRATE THE COST EFFECTIVE FEASIBILITY OF FABRICATING HIGH EFFICIENCY SOLAR CELLS ON CZ WAFERS USING A PULSED EXCIMER LASER FOR JUNCTION FORMATION, SURFACE PASSIVATION, AND FRONT METALLIZATION.

Objectives

I. JUNCTION FORMATION

A. ION IMPLANT PARAMETERS
B. SURFACE CONDITIONS
C. LASER ANNEALING
   - LASER BEAM UNIFORMITY & OVERLAP FACTOR
   - LASER ENERGY DENSITY

II. METALLIZATION
LASER-ASSISTED CHEMICAL VAPOR DEPOSITION

A. DEPOSITION RATE
B. ADHESION
C. PLATE UP

III. SURFACE PASSIVATION (SiO_2)

A. DEPOSITION RATE
B. ADHESION
C. EFFECTIVENESS IN PASSIVATION

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I. JUNCTION FORMATION

A. IMPLANT PARAMETERS

1. IMPLANT ENERGY: SHALLOW JUNCTION REQUIRES LOW KEV
LOWEST AVAILABLE ~5 KEV
OPTIMIZED JUNCTION DEPTH ≥0.25 MICRON

EXTENSIVE SEARCH FOR LOWER ENERGY IMPLANT SERVICES UNSUCCESSFUL.

ALTERNATE APPROACHES INCLUDED:

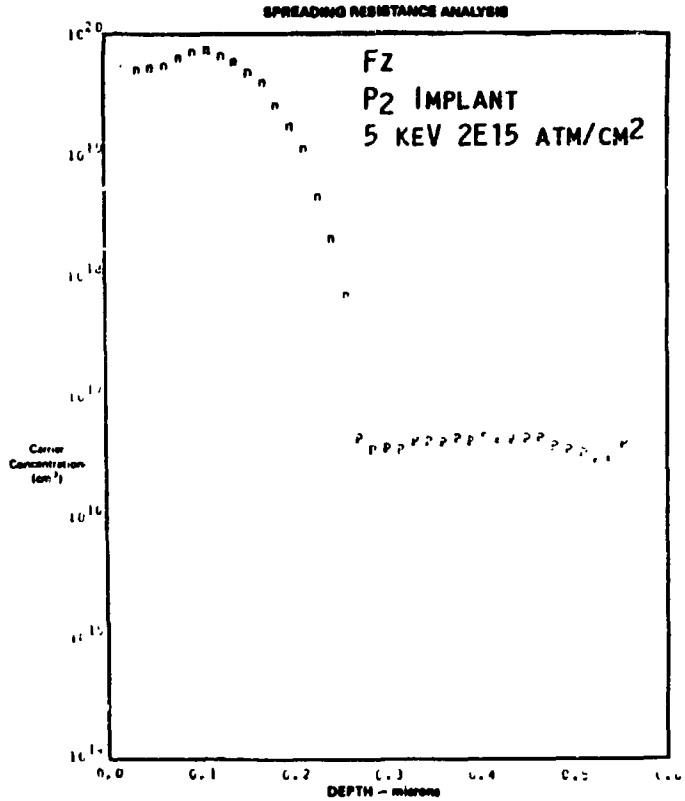
- PH_3, BF_2 MOLECULAR IMPLANT AT CALCULATED ENERGY ~3 KEV (EFF 9.1%)

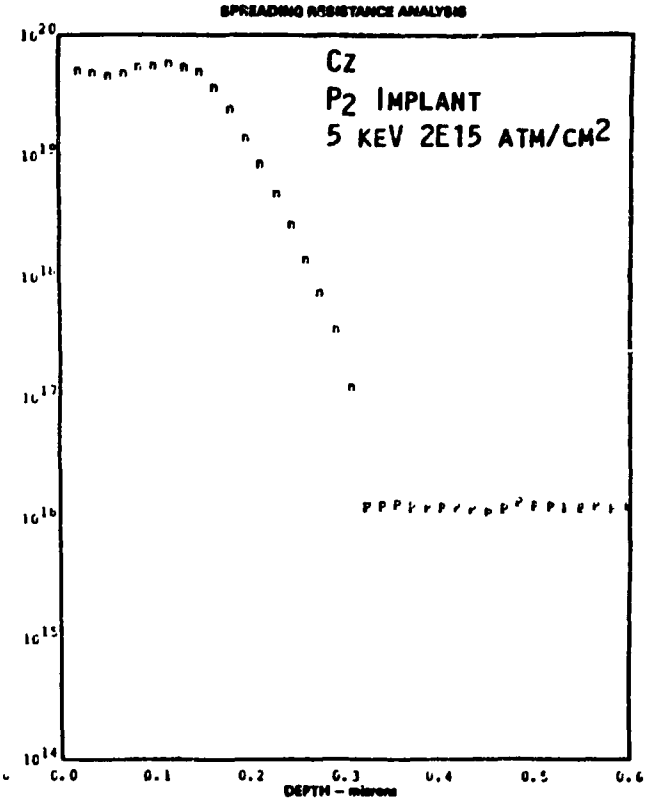
- $^{62}P_2$ ION IMPLANT AT 5 KEV
GOOD RESULT ON FZ MATERIAL (EFF ≥10.8%)
COULD NOT REPEAT ON Cz
DEPTH PROFILE SUGGESTED SLOWER GRADIENT THAN $^{31}P_1$

EMPIRICALLY CHOSEN - 1.8 TO 2.5 X 10^{15} ATOMS/CM^2,
SHEET RHO ~40-60 OHMS/SQ

AGREEABLE TO THE SUGGESTED SURFACE CONCENTRATION PER UNIT AREA FOR CRITICAL MISFIT DISLOCATION GENERATION.

HOWEVER, JUNCTIONS ALWAYS HAVE A DEGENERATE LAYER DEEPER THAN 0.1 MICRON, LIMITING BLUE RESPONSE.


SPREADING RESISTANCE ANALYSIS
Fz
P2 IMPLANT
5 KEV 2E15 ATM/CM2
DEPTH – microns


SPREADING RESISTANCE ANALYSIS
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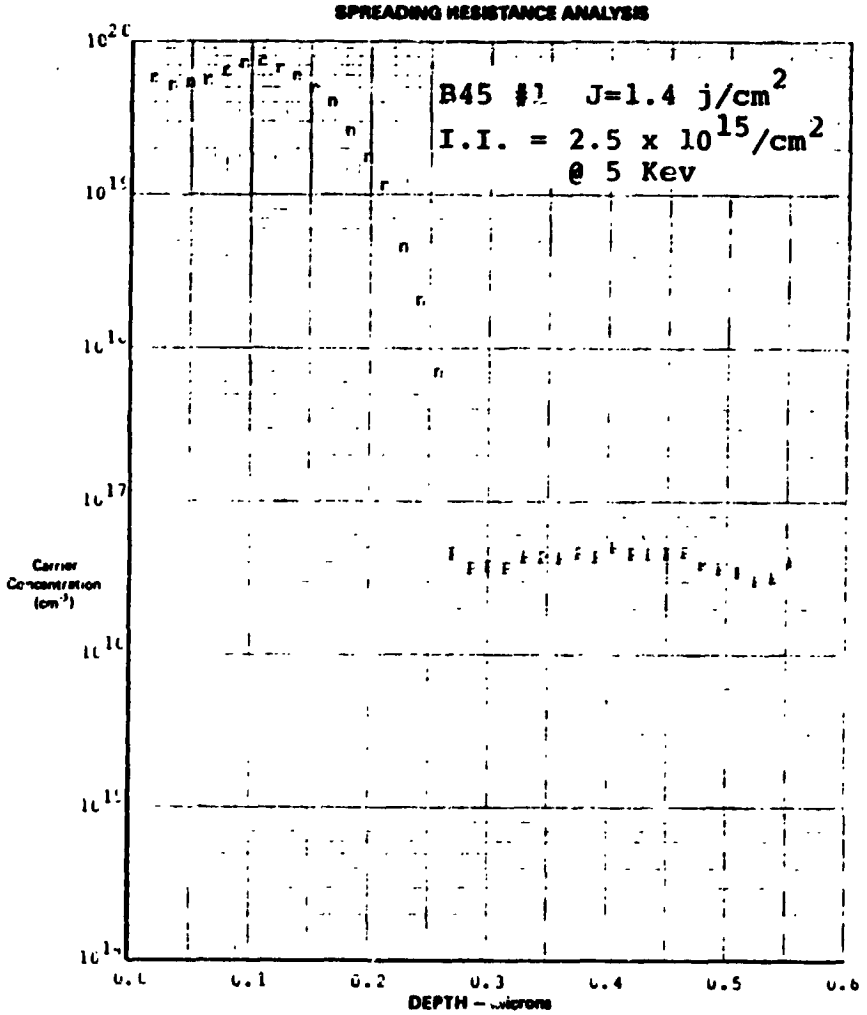

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I.B. SURFACE CONDITIONS

SURFACE CONDITION SERIOUSLY AFFECTED CELL V_{OC} AND FILL FACTOR; MUCH MORE CRITICAL THAN IN CONVENTIONAL THERMALLY DIFFUSED CELL. (LIQUID PHASE DIFFUSION VS SOLID PHASE DIFFUSION.)

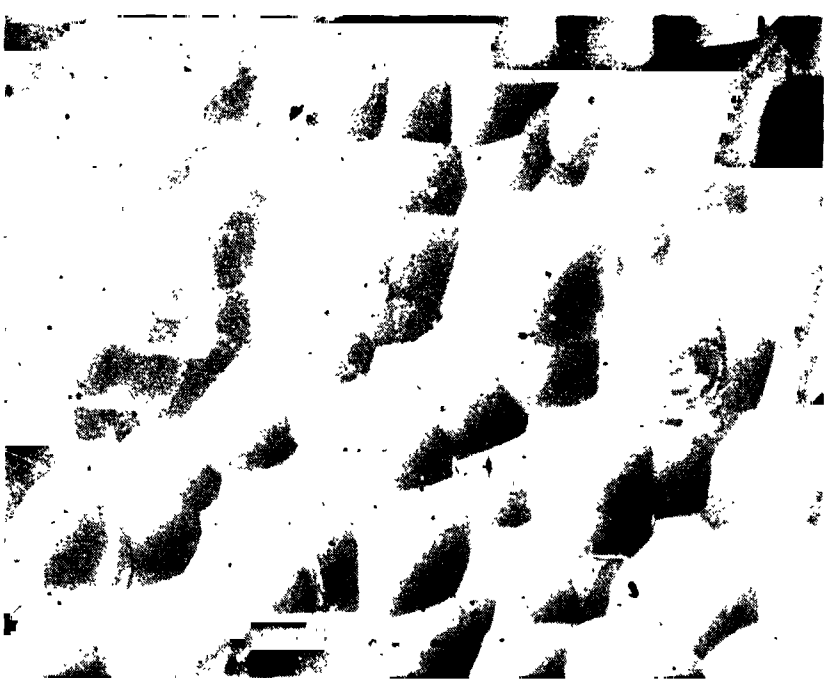
SURFACE FINISHING:

- TEXTURED SURFACE NOT RECOMMENDED FOR LASER ANNEALING; NONUNIFORM MELTING INTRODUCED STRESS ON SURFACE.
- CHEMICALLY POLISHED SURFACE ALSO LOWERED FILL FACTOR, ALTHOUGH TO LESSER EXTENT.
- ONLY HIGH QUALITY CHEM-MECH POLISHED WAFER FOUND SUITABLE FOR THE PROCESS.

SURFACE CLEANING: (BEFORE AND AFTER IMPLANT)

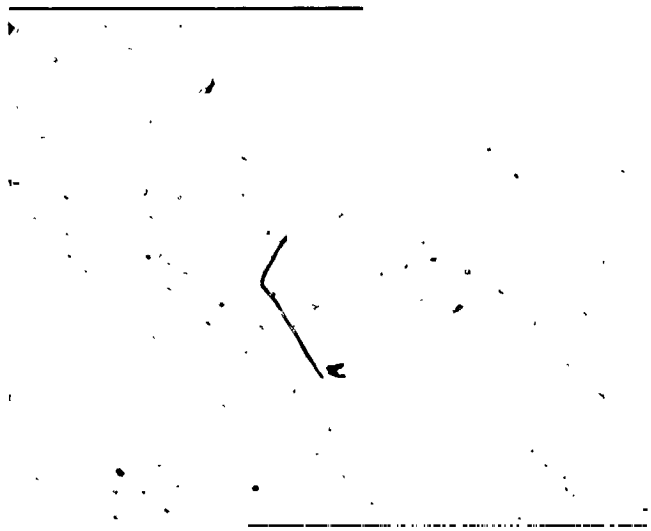
BESIDES STANDARD DEGREASING AND ACID RINSING, ION IMPLANTED WAFER MUST BE SPRAY ETCHED WITH 1% HF FOLLOWED BY SPRAY RINSE WITH 18 MEG-OHM DOUBLE-FILTERED @ 0.2 MICRON ABSOLUTE DI WATER.

Laser-Annealed, Chemically Polished Silicon Wafer



Surface Contamination After Cleaning

Laser Annealed



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Laser Annealed

I.C. LASER ANNEALING

- BECAUSE OF NONUNIFORM LASER (EXCILITE 1) BEAM, OVERLAP FACTOR WAS FOUND BEST AT 50%; 4X ANNEALING ON EACH SPOT.

  HOWEVER, 50% OVERLAP ALSO DRIVES JUNCTION DEEPER THAN DESIRED WITH THE PRESENCE OF A FLAT DEGENERATE LAYER LIMITING BLUE REPONSE.

  JUNCTION MUST BE ETCHED BACK IN $HF:HNO_3$ SOLUTION IN ORDER TO RECOVER SHORT WAVELENGTH RESPONSE.

- ENERGY DENSITY
  EMPIRICALLY FOUND ~1.5 J/cm^2

  LOWER THAN 1.4 J/cm^2 -- INCOMPLETE ANNEALING
  HIGHER THAN 1.6 J/cm^2 -- SURFACE DAMAGE

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Surface Damage at 1.6 j/cm^2, 50% Overlap

II. METALLIZATION

CONDITIONS: ArF AT 198 nm, OUTPUT ENERGY ~15 mJ
ENERGY DENSITY ~1.2 J/cm^2.

REACTION CHAMBER PRESSURE ~5 torr, BEAM PERPENDICULAR TO SURFACE.

CHEMICAL REACTION: $WF_6 + 3H_2 \xrightarrow{h\nu} W + 6HF$

RESULTS (PRELIMINARY):

- TUNGSTEN LINE OBTAINED ~5-10 mils WIDE
- PASSED TAPE TEST
- THICKNESS ~500-1000Å (250 SHOTS):
  HOWEVER, DOUBLE HUMP STRUCTURE: FLAT AT THE CENTER.
- EXACT METAL COMPOSITION IS BEING DETERMINED BY AUGER ANALYSIS.

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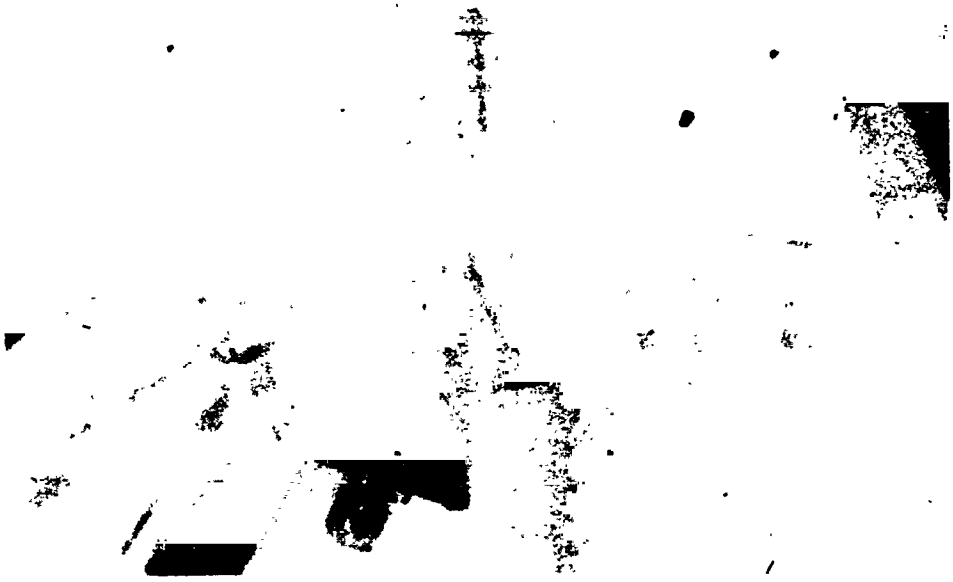

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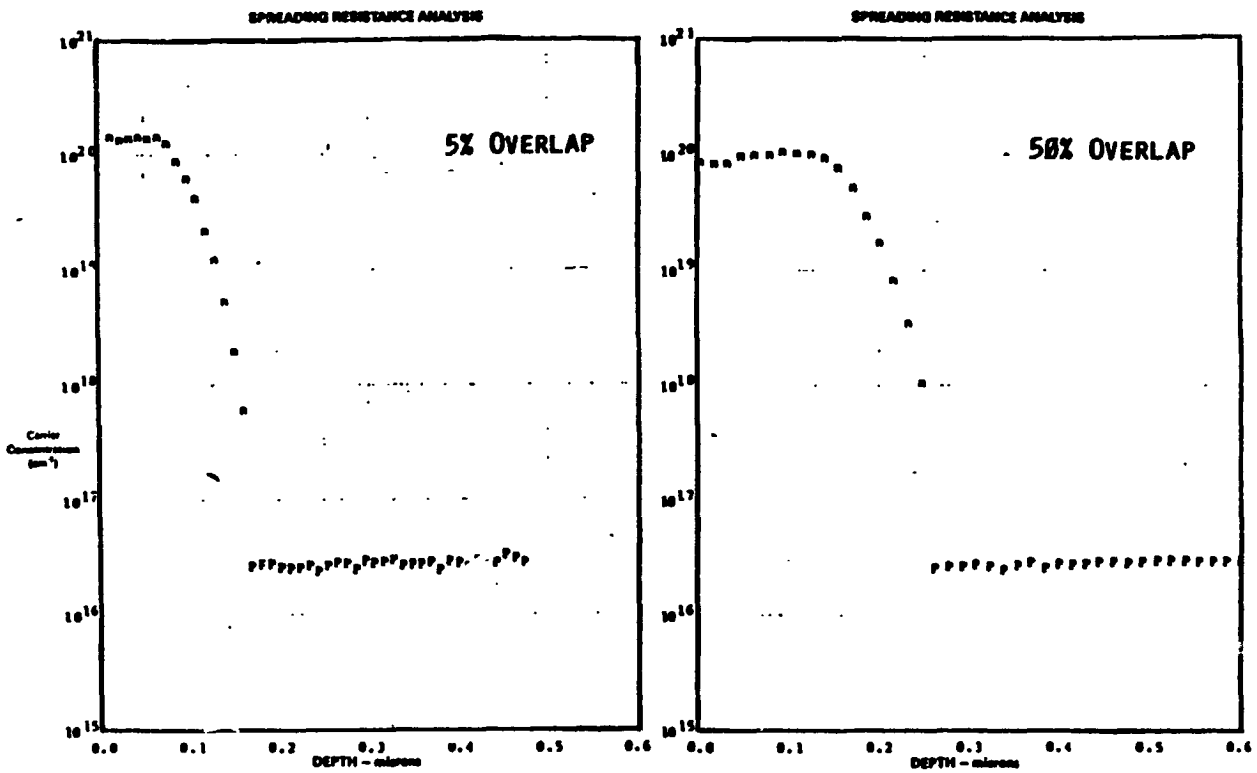

JUNCTION DEPTH PROFILES OF 1.4 J/CM^2 LASER-ANNEALED SAMPLES WITH 5% AND 50% OVERLAP.

(RESULTS FROM COLLABORATIVE PROJECT BETWEEN ARCO SOLAR AND OAK RIDGE NATIONAL LABORATORY)

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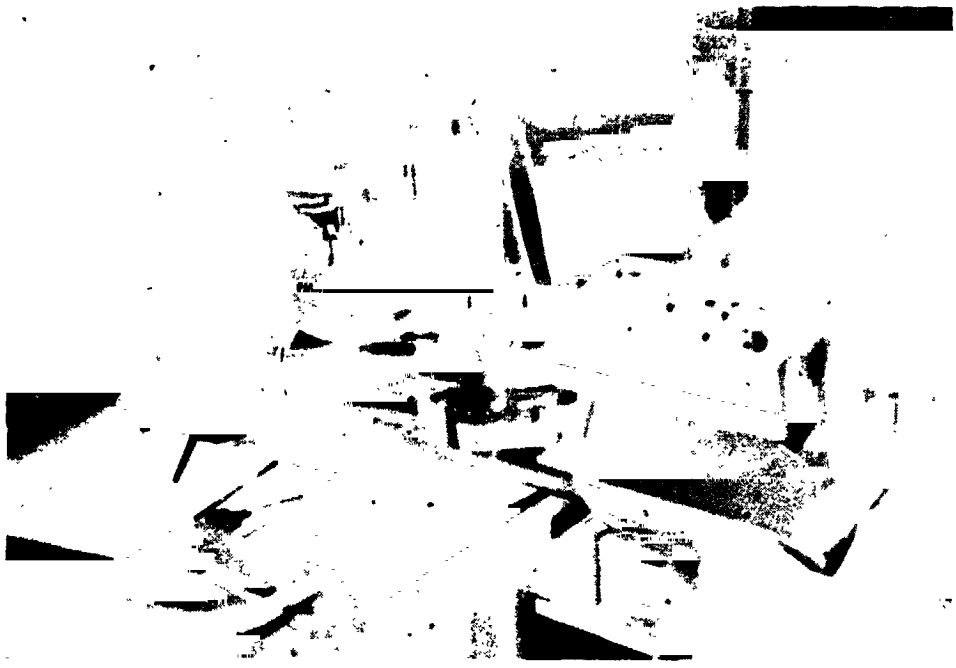

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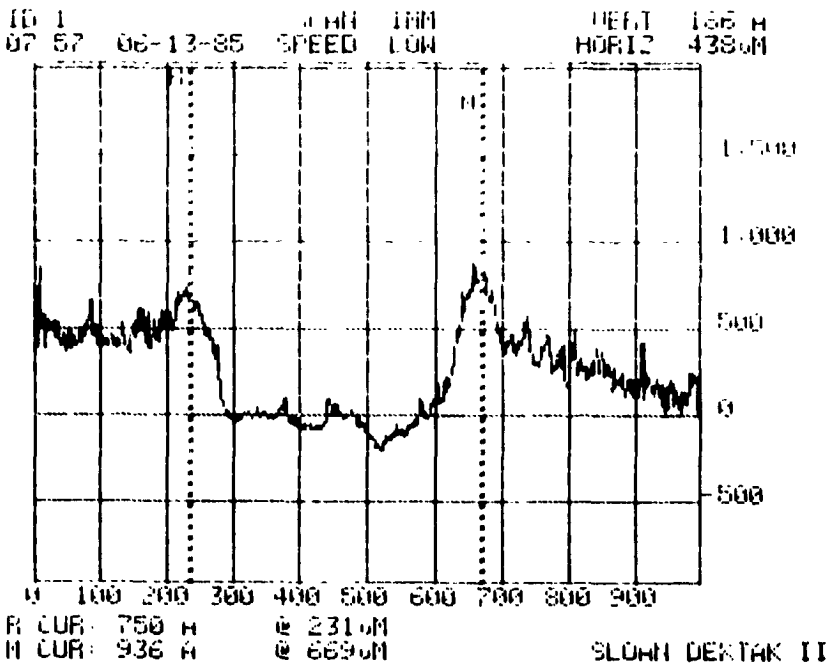


DEKTAK MEASUREMENT ACROSS THE DEPOSITED METAL LINE. NOTE THE VALLEY IS <u>BELOW</u> THE WAFER SURFACE.

III. SURFACE PASSIVATION

CONDITIONS: ArF AT 198 nm, OUTPUT ENERGY - MAX

CHAMBER PRESSURE ~6-10 torr, BEAM PARALLEL TO WAFER SURFACE.

CHEMICAL REACTION: $SiH_4 + 4N_2O \xrightarrow{h\nu} SiO_2 + 2H_2O + 4N_2$

DEPOSIT RATE ~600°-800°A/Min

(Experiment to be performed)

Summary of Achievements

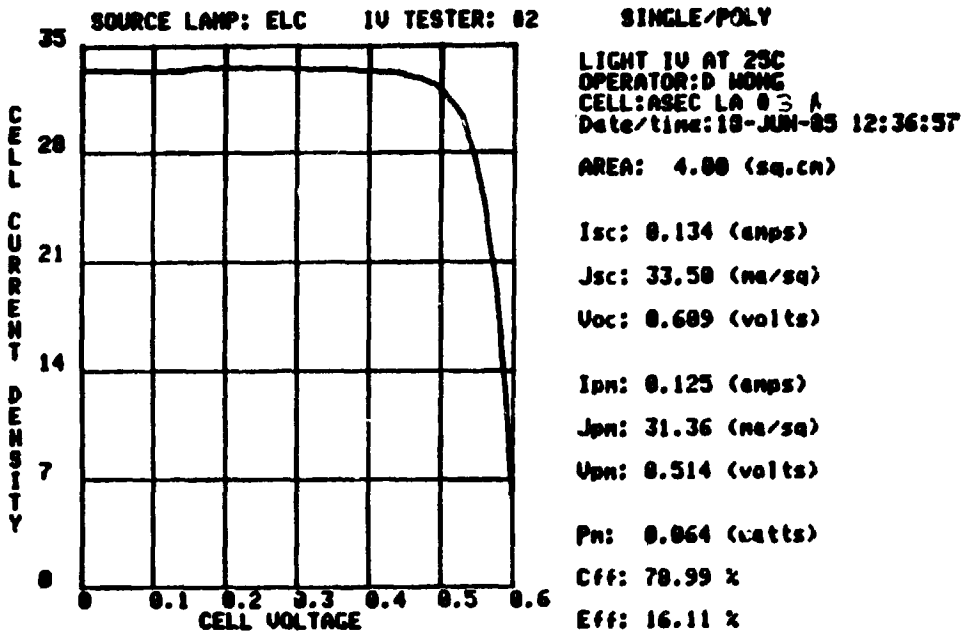
1. BATCH MODE LASER ANNEALING ACCOMPLISHED ON 50 2"x2" Cz WAFERS.

   BEST CELL EFFICIENCY AFTER AR COATING IS 16.1% (WITHOUT BSF).

   SPECTRAL RESPONSE IS SUPERIOR TO COMMERCIAL THERMALLY DIFFUSED CELL (WITH BSF) IN BLUE WAVELENGTH.

   LOWER V_{OC} IN LASER ANNEALED WAFER IS DUE TO LASER BEAM EDGE DAMAGE.

2. LCVD TUNGSTEN LINES ON SILICON SURFACE SUCCESSFULLY DEPOSITED WITH GOOD ADHESION.



ASEC CONTACTS AND A/R
LASER ANNEALED
SURFACE DIRTY, HEAT TREATED

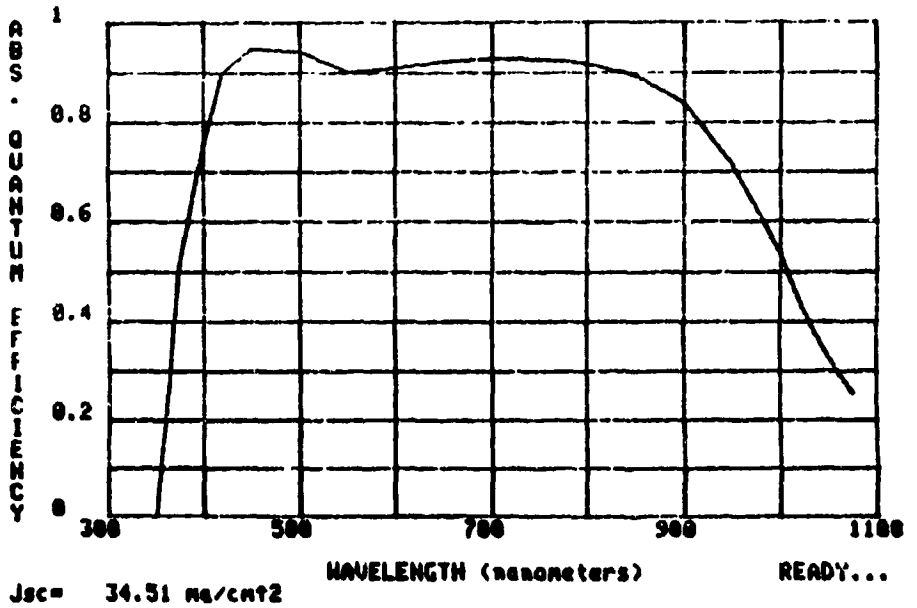
B62 LASER ANNEALED a
1.47 J/cm^2

Sample: ASEC METALIZATION, HEAT TREATED #3

Voltage: 0.000 Volts Light Bias: N

Date/time:18-JUN-85 15:45:44 Operator: D WONG

System Calibrated 18-JUN-85 15:21:06 Standard Cell #325



Jsc= 34.51 ma/cm2

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DAMAGES AT THE LASER BEAM EDGES THAT LED TO V_{OC} DEGRADATION.

Problems

1. JUNCTION FORMATION

   PROCESS EXPENSIVE AND TIME-CONSUMING. CELL EFFICIENCY MATCHES BUT IS NOT HIGHER THAN CONVENTIONAL THERMAL PROCESS.

2. UNABLE TO PROCESS LARGE AREA (5") CELLS DUE TO LACK OF ION IMPLANT FACILITY.

3. METALLIZATION

   SLOW PROCESS. SILVER PLATING ON TUNGSTEN IS QUESTIONABLE.

4. PASSIVATION

   CAN CVD SiO_2 DEACTIVATE THE DANGLING SILICON BONDS ON THE SURFACE?